The Isokusa Formation and its Late Upper Jurassic and Early Lower Cretaceous Ammonite Fauna

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The Isokusa Formation and its Late Upper Jurassic and Early Lower Cretaceous Ammonite Fauna

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Abstract

The Isokusa Formation, the uppermost part of the Shishiori Group can be divided into three units at Niranowaki on the east coast of Oshima Island, southern Kitakami Massif, northeast Japan: 1) Sandy mudstone of the lowest part (IK-1) yielded *Berriasella* sp., an unidentified gigantic perisphinctid and fossils of pelecypod, echinoid and coral; fragmental fossil plants also occur, 2) Clayey and silty shale in the middle (IK-2) yielded abundant *Substeueroceras* sp. and a few trigonians, and 3) Black fine grained sandstone in the upper (IK-3) yielded one *Berriasella* sp. from the lowermost part and one *Thurmanniceras isokusense* from the upper. The black fine grained sandstone and sandy mudstone at the sea coast of Isokusa on the west coast of Oshima Island, corresponds to IK-3 at Niranowaki in lithofacies. *Ptychophylloceras* sp., *Berriasella* spp. and *Protacanthodiscus akiyamai* occurred from the lower part of the Isokusa sequence and *Thurmanniceras isokusense* abundantly from the upper part. Fine grained sandstone and black mudstone at Nagasaki on the east coast of Oshima Island, yielded *Olcostephanus* sp., *Spiticeras* cf. *binodiger*, *Berriasella* sp. (ex. gr. *B. berthei*), *Protacanthodiscus* aff. *malbosi* and *Kilianella* sp. Among them *Olcostephanus* sp. is abundant in the middle part and the others are of uncertain horizons, but probably from the lower part of the sequence where the sediments are somewhat coarser and rich in pelecypod fossils.

The boundary between the Tithonian (Jurassic) and Berriasian (Cretaceous) is tentatively drawn between Ik-2 and Ik-3 in the Niranowaki sequence. The horizon of *Olcostephanus* is Valanginian in age according to universal acceptance of ammonite genera.

INTRODUCTION AND ACKNOWLEDGMENT

The stratigraphic relation between the Upper Jurassic and Lower Cretaceous rocks in the southern Kitakami Massif has not been settled, and in this concern, an attempt is made to clarify the stratigraphic and paleontologic relation between the Kogoshio and the Isokusa formations in the southern Kitakami Massif.

Field study was undertaken mainly on Oshima Island where the known Upper Jurassic and Lower Cretaceous rocks are distributed, and the ammonite fauna of Oshima Island was re-examined from the biostratigraphic view point.

Ammonites are known from the localities of Niranowaki, Isokusa, Nagasaki and Shiraitohama. The last locality yielded only one Hauterivian (or Lower Barremian) species, and *Crioceratites ishiwarai* is out of the scope of this work. The ammonites from the three other localities were studied by Kobayashi and Fukada (1947), Sato (1958, 1961, 1962) and the writer (Takahashi, 1969) published brief notes without description. The localities were re-examined stratigraphically and paleontologically by the writer during the spring of 1971 to the summer of 1972 and new collections were made.

The Late Upper Jurassic and Early Lower Cretaceous stratigraphy and paleontology of the ammonites of the area are presented based on the previous and newly obtained materials, and the information now available is summarized with reference to the boundary

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between the Jurassic and Cretaceous systems of the island.

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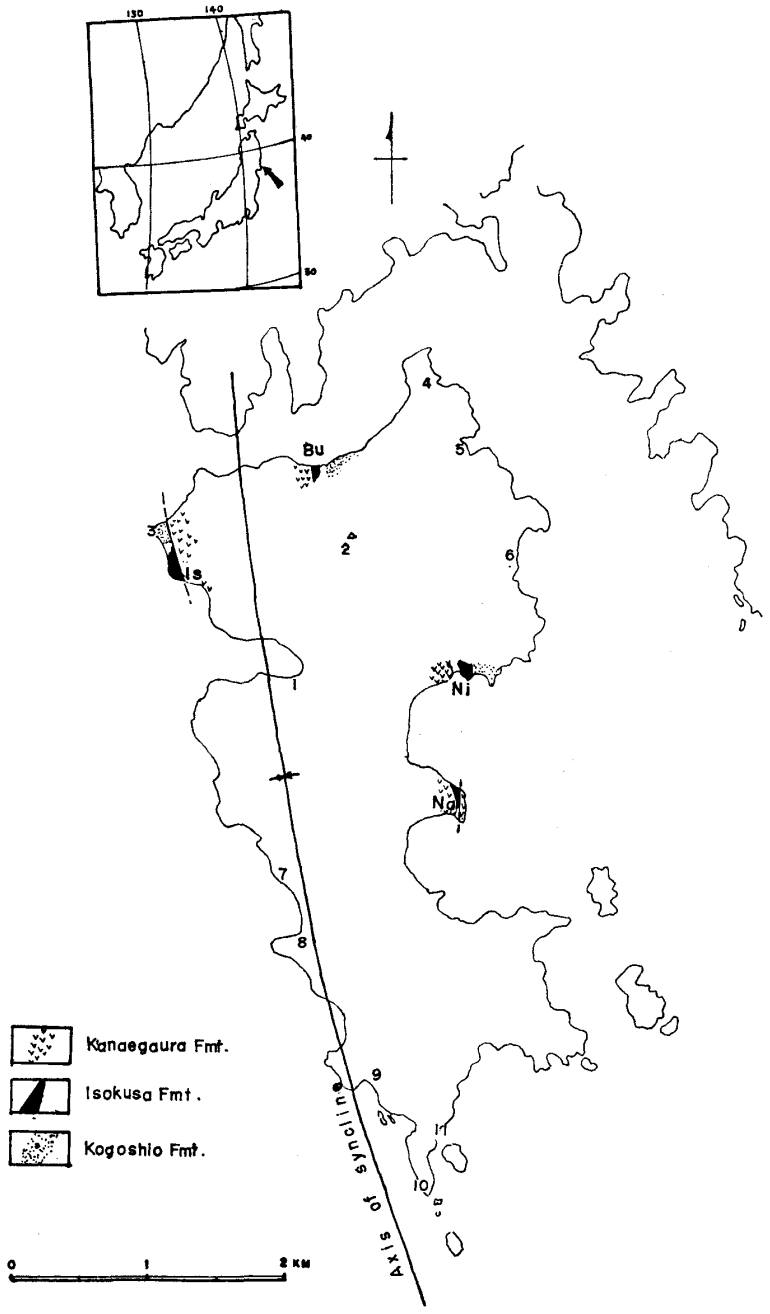

Fig. 1. Map showing the localities of the Isokusa Formation and some other localities. Distribution of the Isokusa Formation is somewhat emphasized.
Ni Niranowaki (=Wakagihama); Bu Budo; Is Isokusa; Na Nagasaki; 1 Uranohama; 2 Kameyama; 3 Ippaimori; 4 Sotohama; 5 Udohama (=Utohama); 6 Kugunarihama; 7 Asane; 8 Yogai; 9 Yokonuma; 10 Tatsumaisaki; 11 Shiraitohama.

Department of Geology, Hirosaki University, Hirosaki, for their useful discussions and informations. Mr. Itaru Murakami, Department of Geology, Ibaraki University, Mito made available his detailed stratigraphical data and offered many fossils for the present study. Professor Toshiji Oyama and Associate Professor Toshio Saito of the same Department supported the study in various ways.

OUTLINE OF GEOLOGY OF OSHIMA ISLAND

Geologically Oshima Island belongs to the Karakuwa Area of the Central Belt of the southern Kitakami Mesozoic Region (Takahashi, 1969, p. 24), and is located in the axial area of the Tsunagizaka synclinal basin (Shiida, 1940, p. 34, p. 63).

The sediments of Oshima Island range from the Late Jurassic to Quaternary; the Pliocene Senganda Formation, diluvial terrace gravels (Matsuzaki Formation of Shiida) and alluvial deposits have but small distribution on the island. The Mesozoic rocks are arranged in general from the north to south in ascending order with a synclinal structure which axis trends N-S. They contain the Mone, Kogoshio, Isokusa, Kanaegaura, and Oshima (=Yokonuma of Onuki, 1969) formations in ascending order.

The Mone Formation that lacks its lower half in the island is composed mainly of fine to medium grained arkose which sometimes grades up to subarkose, in general micaceous, colored light brown on slightly weathered surface, and layers of dark colored clayey and silty shale are frequently intercalated. Autochthonous clusters of pelecypod fossils, mainly trigoniids, occur infrequently in the sandstones and rich land plant fossils occur from the shales and sometimes from the sandstones.

The Kogoshio Formation is composed mainly of thick bedded coarse to very coarse grained arkose and subarkose and plant fossils occur in the argillaceous layers less frequently than in the Mone Formation. A peculiar calcareous sandstone layer (6 m thick) in the lower part of the formation contains cobbles and pebbles of oolitic and pisolitic limestones of micritic matrix (Hayami, 1961, p. 181). These are intraformational and of probable penecontemporaneous origin reworked from an unidentified reef.

Both the Mone and Kogoshio formations are generally arenaceous and massive, and usually do not reveal stratification but at several horizons cross-stratifications and at some localities the sandstones of the Mone Formation show thin to medium stratification. The sediments of both formations are essentially not pure marine, but represent rather mixed environments such as shore or estuary or marine delta in which sedimentation sometimes extends into the alluvial plain as in the Upper Jurassic "quartzose sandstone" of the Soma region reported by Okami (1969).

Distinction between the Mone and the Kogoshio formations has been chiefly made by the character of grain size (Shiida, 1941, p. 904), finer grained sandstones being predominant with frequent argillaceous layers in the former and predominant coarser grained sandstone with less frequent argillaceous layers in the latter. Thus the boundary falls between Mn -0 and Kg-1 (base of conglomeratic layer) in the succession (Fig. 2).

The stratigraphic position of the Isokusa Formation has been obscure because of being isolated from the main distribution area of the Shishiori Group and only small exposures at the west coast of Isokusa and at the east coast of Nagasaki, were known where the direct stratigraphic relation with the adjacent formations could not be determined.

Recent field observations show that the argillaceous layers lying on the arenaceous layers in the upper part of Kogoshio Formation at Niranowaki, east coast of the island, treated as the uppermost part of the Kogoshio Formation by most authors should be put into the Isokusa Formation because of 1) general resemblance of lithology of the sequence at Niranowaki to that of Isokusa and Nagasaki, and 2) *Thurmanniceras isokusense*, a

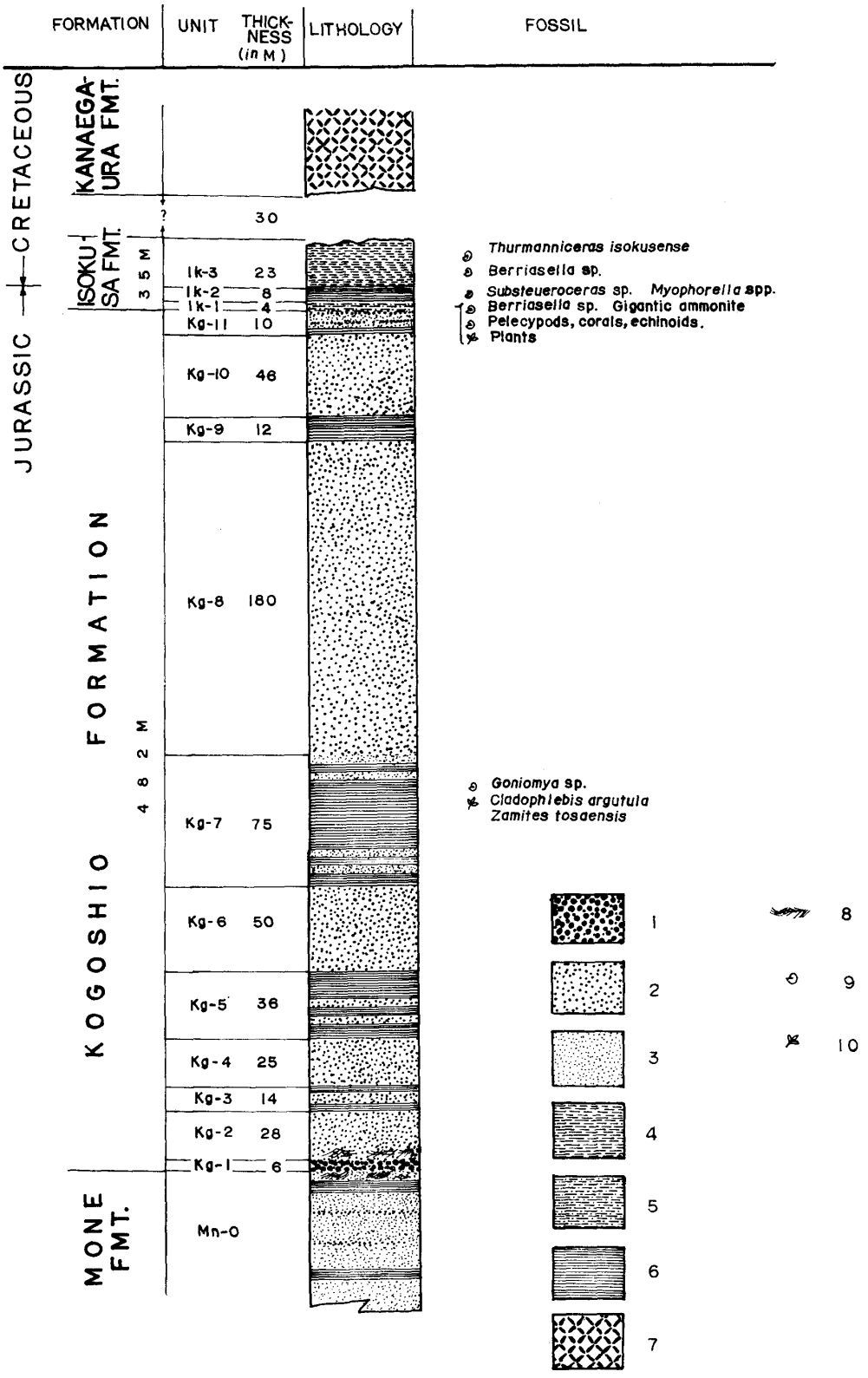

Fig. 2. Columnar section of the Shishiori Group (part) at the east coast of Oshima Island. 1, Conglomerate; 2, Coarse to very coarse grained sandstone (subarkose and arkose); 3, fine to medium grained sandstone (arkose and subarkose); 4, Black sandy mudstone; 5, Calcareous sandy mudstone; 6, Shale; 7, Volcanics; 8, Cross stratification; 9, Animal fossil; 10, Plant fossil.

characteristic ammonite of the Isokusa Formation, occurs from the upper part of the sequence at Wakagihama. The stratigraphic relation of the Isokusa Formation to the subjacent formation is a conformity as pointed out by some authors.

The Isokusa Formation was deposited in a shallow neritic marine environment, in contrast to the mixed environment of the Mone and Kogoshio formations.

The boundary of the Isokusa Formation with the subjacent Kogoshio Formation should be drawn between Kg-11 and Ik-1 (base of fossiliferous layer) (Fig. 2).

The relation of Isokusa Formation to the superjacent Kanaegaura Formation of various types of volcanic products and complex structure has not been determined; it is here treated as an unconformity following most authors.

The upper part of the Kanaegaura Formation merges into the Oshima Formation that consists of sandstone, shale, and their alternation, tuffaceous sandstone, calcareous sandstone, and impure limestone of biohermal origin. Abundant fossils of bivalves, gastropods, and corals occur at several localities; *Crioceratites ishiwarai* (Yabe and Shimizu, 1927) occurs from the upper part of the formation at Shiraitohama, southeast coast of the island. The age of this ammonite may be Hauterivian or Lower Barremian.

STRATIGRAPHY OF THE ISOKUSA FORMATION

The Isokusa Formation as defined above is exposed at four places on Oshima Island; namely 1) Niranowaki (Wakagihama of authors), 2) Isokusa, 3) Nagasaki, and 4) Budo. Among them the last place has not yielded any ammonite and is thus omitted here.

Wakagihama: – Wakagihama is known as a fossil locality of plants (Shiida, 1941), bivalves (Hayami *et al.*, 1960) and ammonites (Sato, 1962). The stratigraphic position of the argillaceous layers at Niranowaki was considered to be the middle part of Mone Formation by Shiida (*loc. cit*), but most recent authors treat it as the uppermost part of the Kogoshio Formation. The succession taken from the east of Niranowaki is as follows [upper part of Mone Formation and lower part of Kogoshio Formation (Kg-1 ~Kg–9) are omitted]:

Kg-10 Sandstone: Thick bedded, angular, coarse-very coarse-granule arkose and subarkose; color whitish, weathering to light yellow to brown; coarse-grained sandstone mainly subarkose, very coarse and granule sandstone mainly arkose (much feldspars and matrix and/or voids, generally more angular). Thickness of 46 m. Barren of fossils.

Kg-11 Sandstone and shale: In ascending order, shale (1 m); gray colored, fine grained arkose (ca. 1.5 m); alternation of fine grained sandstone and coarse grained sandstone (2 m); gray, fine grained arkose (4 m); whitish, coarse grained subarkose (ca. 1 m). Thickness ca. 10 m. Barren of fossils.

Total thickness of Kogoshio Formation (Kg-1 ~Kg-11) is 482 m.

——————— Boundary of formations ———————

Ik-1 Sandy mudstone: Moderately fissile, black to dark gray in slightly weathered state, calcareous and bituminous, sometimes mottled sandy mudstone with scattered quartz grains. Thickness ca. 4 m. Fossils abundant, both animals and plants.

Ammonoid: *Berriasella* sp., *Substeueroceras* sp., Gigantic perisphinctid (dorsoplanitinid or tolinid).

Pelecypod: *Nuculana* (*Praesaccella*) sp. ex gr. *N. yatsushiroensis* Tamura, *Parallelodon* (s.s) *kesennumaensis* Hayami, *P.* (*Trinosucatella*) *kobayashii* (Tamura), *Grammatodon* sp., *Gervillia* sp., *Pleuromya* sp., *Myophorella* sp., *Arcomytilus* sp.

These pelecypods except the last two species were described by Hayami (in Hayami *et al.*, 1960). *Myophorella* and *Arcomytilus* are newly listed here. *Arcomytilus* sp. is a species unknown from Japan, and occurs from a recent exposure in the upper part of this unit.

Coral: *Trochocyathus* (*Platycyathus*) aff. *harveyanus* Milne-Edwards and Haime. (after Hayami, 1960)

Plant: *Nilssonia orientalis* var. *minor* Font., *Neocalamites* sp., *Sphenopteris* sp., *Equisetites* sp.

The following species are listed from Niranowaki by Shiida (1941, p. 901, Locality Number 13 of Table 3); the exact horizon of this flora is not known but is tentatively considered as of this unit.

Matonidium Göpperti (Ett.), *Gleichenites comptonifolius* Seward, *Cladophlebis browniana* (Dunker), *Zamites oshimana* Kondo, *Z. ishiwarana* Kondo, *Z. buchianus* Seward, *Otozamites contignus* Feist., *Pterophyllum Lyellianum* Dunker, *P. nerbuddaicum* Feist.

These species seem to need re-examination.

Ik-2 Black shale: Black, lustrous, bituminous shale, partly slaty, a calcareous sandy layer (1.5 m thick) intercalated. Thickness of 8 m. Abundant ammonites, a few pelecypods and plant fragments.

Ammonoid: *Substeueroceras* sp.

Pelecypod: *Myophorella* (*Promyophorella*) *orientalis* Kobayashi and Tamura, *M.* (*P.*) *obsoleta* Kobayashi and Tamura.

Substeueroceras is common throughout this unit, being especially rich in the middle part.

Ik-3 Sandy mudstone: Generally massive to moderately bedded (not slaty), black to dark gray, carbonaceous and ferruginous, mottled, fine to very fine sandstone and siltstone; That is to say "black sandy mudstone". Thickness 23 m, top of the succession eroded out. Fossils rare.

Ammonoid: *Berriasella* sp., one specimen from the base of this unit. *Thurmanniceras isokusense* (Kobayashi and Fukada), one specimen obtained from the beach gravel in front of the cliff from where it was probably derived; corresponding to the top of the succession.

The top of this unit is cut off by a cove and beach. The cliff behind the beach consists of andesitic lava and tuff of the Kanaegaura Formation. The strata missing amounts to about 30 m in thickness. The boundary between the Isokusa and Kanaegaura formations is somewhere along this beach.

Total thickness of the Isokusa Formation at Niranowaki is 35 m.

Isokusa: – The argillaceous layers at the west coast of Isokusa village are disturbed by many faults and foldings. The strata, however, have general dips of 30–70 degrees to south or southeast.

The lithology of the strata is similar to that of Ik-3 at Niranowaki. The rocks are massive to moderately bedded, black to dark gray, very fine grained sandstone and siltstone; they are in general mottled. The thickness of the formation at Isokusa is about 50 m. Fossils are rich in ammonites and sporadic in pelecypods, gastropods and echinoids.

Ammonoid: *Ptychophylloceras* sp., *Berriasella* spp., *Protacanthodiscus akiyamai* (Sato), *Substeueroceras* ? sp., *Kilianella* sp., *Thurmanniceras isokusense* (Kobayashi and Fukada).

The last listed species is abundant in the upper part of the sequence, *Kilianella* is represented by one fragmental specimen from the horizon of *Thurmanniceras*, and the others occur from the lower part. The identification and locality of *Substeueroceras*? sp. is doubtful.

Pelecypod (after Hayami *et al.*, 1960): *Parallelodon* (*Torinosucatella*) *kobayashii* (Tamura),

Grammatodon (s.s.) *takiensis* Kimura, *Variamussium* cf. *habunokawaense* (Kimura), *Limatula akiyamae* Hayamai, *Myophorella* (*Promyophorella*) cf. *orientalis* Kobayashi and Tamura, *M.* (*P.*) *obsoleta* Kobayashi and Tamura.

Nagasaki: – The Isokusa Formation has small distribution at the tip east of Nagasaki village, east coast of the island. The base of the succession is cut by a fault and is in contact with andesitic tuff of the Kanaegaura Formation. The top of the succession is covered by andesitic lava of the Kanaegaura Formation.

Lithology of the Isokusa Formation of Nagasaki is more or less similar to that of Isokusa and Niranowaki. The thickness is about 35 m. Fossils are generally sporadic. The calcareous layer at the lower part yielded pelecypod fossils but they are fragmental and unidentifiable.

Ammonoid: *Spiticeras* (*Spiticeras*) cf. *binodiger* Uhlig, *Olcostephanus* sp., *Berriasella* sp., *Protacanthodiscus* aff. *malbosi* (Pictet), *Kilianella* sp.

Olcostephanus occurs from the middle part of the succession. Others are uncertain as to exact horizons, but they are possibly from the lower part of the succession.

Pelecypod (after Hayami *et al.*, 1960): *Grammatodon* (s.s.) *takiensis* Kimura, *Grammatodon* sp., *Limatula akiyamae* Hayami, *Myophorella* (*Promyophorella*) cf. *orientalis* Kobayashi and Tamura, *M.* (*P.*) *obsoleta* Kobayashi and Tamura, *Astarte* cf. *spitiensis* Stoliczka, *Astarte* sp., *Pleuromya* sp.

GEOLOGIC AGE OF ISOKUSA FORMATION

The Isokusa Formation in Oshima Island may be Upper Tithonian to Valanginian in terms of chronostratigraphic divisions of the Tethyan (*sensu lato*) realm.

Strict chronostratigraphic or geochronologic correlation between Japan and Europe or South America is hardly possible, especially in the case of fossils being so scarce as in the Kitakami Jurassic and Cretaceous. However, in the case of ammonites it is possible to define the age by taking consideration their short ranges and probable acme of the genus.

The horizon of *Substeueroceras* sp., the lowest marked ammonite horizon of the Isokusa Formation, was correlated with the *Substeueroceras koeneni* zone of the Andean Jurassic by Sato (1961), though the genus extends into the Cretaceous.

The *Substeueroceras koeneni* zone is generally accepted as an equivalent of the *Berriasella chaperi* zone of southeast France and the upper part of the *Virgatosphinctes ? transitorius* zone of the Alpine Jurassic (Arkell, 1956; Enay, 1964, etc.), and all are the uppermost zones of the Jurassic. Some South American authors assign the *Substeueroceras koeneni* zone to an age somewhat younger than the latest Tithonian.

The horizon of *Substeueroceras* in the Isokusa Formation is correlated with the *Substeueroceras koeneni* zone and assigned to the latest Tithonian age. The occurrence of a gigantic ammonite that is likely to be a member of the famous Upper Jurassic Group, from the horizon just below that of *Substeueroceras* may support the view.

The horizon of *Protacanthodiscus akiyamai*, the second horizon, with coexistent *Berriasella* spp. and the long ranged *Ptychophylloceras* sp. in the lower part of the sequence of Isokusa can be correlated with the Berriasian by their general aspect. The horizon of *Berriasella* sp. at Niranowaki (lower part of Ik-3) and the lower part of the sequence at Nagasaki from which *Spiticeras* (*Spiticeras*) cf. *binodiger*, *Berriasella* sp., *Protacanthodiscus* aff. *malbosi* and *Kilianella* sp. presumably occur are probably age equivalent to the horizon of *P. akiyamai*.

The horizon of *Thurmanniceras isokusense*, the third horizon, with a fragment of

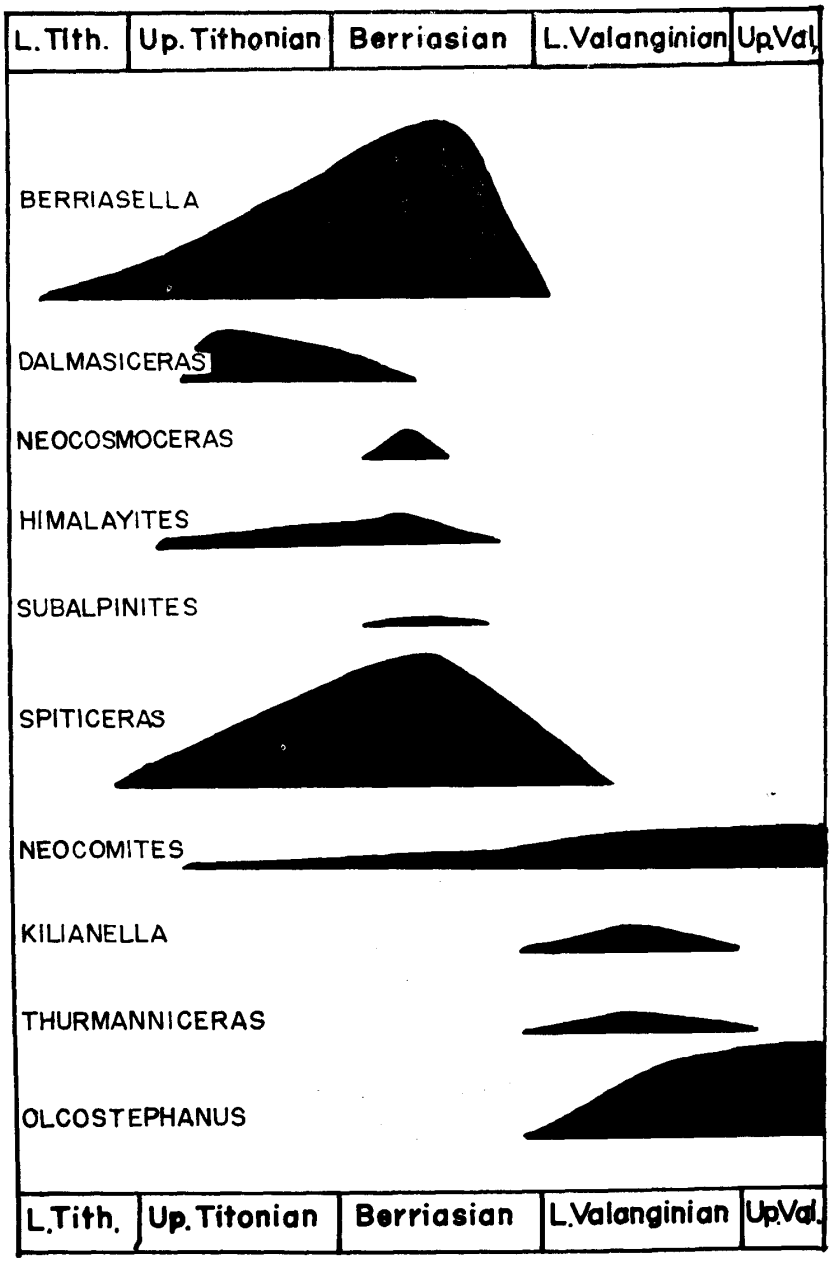

Fig. 3. Frequency of ammonite species in characteristic group in Tithonian-Berriasian-Valanginian of Europe (after Busnardo and Le Hégarat, 1965).

Kilianella sp. may be rather Lower Valanginian than Berriasian because the range and acme of both *Thurmanniceras* and *Kilianella* fall in the Lower Valanginian (not Infra-Valanginian). The upper part of the Niranowaki sequence which yielded *Thurmanniceras isokusense* is considered to be age equivalent to this horizon.

The horizon of *Olcostephanus* sp., the fourth and uppermost horizon, can be correlated to the Middle and/or Upper Valanginian.

The absence of *Thurmanniceras* at Nagasaki, which should occur between the supposed equivalence of the subjacent horizon of *Protacanthodiscus akiyamai* and the horizon of *Olcostephanus* sp. is a problem. The problem may be solved by further detailed survey and fossil collecting at the outcrops at Nagasaki.

In conclusion the chronostratigraphic boundary between the Tithonian (Jurassic) and Berriasian (Cretaceous) can be drawn between Ik-2 and Ik-3 of the Niranowaki

sequence; this horizon is probably not present at Isokusa and Nagasaki. The boundary between the Berriasian and Valanginian is drawn between the lower and upper parts of the Isokusa sequence and somewhere between the horizon of *Olcostephanus* and the lower part of the sequence at Nagasaki.

As discussed above the chronostratigraphic boundaries are more or less tentative and applied only to the regional correlation for convenience.

The boundary between the Jurassic and Cretaceous systems in this area does not coincide with the lithostratigraphic boundary defined by change in lithology as mentioned by Sato (1961a, p. 537).

SYSTEMATIC PALEONTOLOGY

The material upon which this paper is based is preserved in the Institute of Geology and Paleontology, Tohoku University, Sendai and the Department of Geology, Ibaraki University, Mito. The registered numbers of the specimens abbreviated IGPS coll. cat. no. are in the collection of the former institute and those abbreviated GIUM are in the collection of the latter department.

All the specimens are more or less crushed and deformed, therefore the following descriptive terms are used for dimensions of specimens (after Matsumoto, 1954):

very small	less than 3.5 cm in diameter
fairly small	3.5–7.5 cm
moderate	7.5–12.5 cm
fairly large	12.5–25 cm
very large	25–50 cm
gigantic	more than 50 cm

Class Cephalopoda Cuvier, 1797
Subclass Ammonoidea Zittel, 1884
Order Phylloceratida Arkell, 1950
Superfamily Phylloceratacеae Zittel, 1884
Family Phylloceratidae Zittel, 1884
Subfamily Calliphyloceratinae Spath, 1927
Genus *Ptychophylloceras* Spath, 1927

Type-species: – *Phylloceras feddeni* Waagen, 1875

Synonyms: – *Tatroceras* Kovacs, 1939; *Neumayriceras* Sorrentino, 1942 (non Rollier, 1909).

Ptychophylloceras sp.

Material: – One fragmental specimen. GIUM 40768

Remarks: – A fragment of a fairly small (about 60 mm in diameter) ammonite represented by both internal and external molds was obtained from a sandy mudstone at the west coast of Isokusa. It has strongly involute whorl with moderately round flank side and venter. Both internal and external surfaces smooth except for fairly distant constrictions that accompany faint ribblets (labial ridges) on both adapical and adoral sides. The riblets are slightly elevated at the ventral margin, especially the adapical one is conspicuous. Three constrictions are observed but probably seven or eight constrictions may be present on intact whorl.

The smooth surface with periodic elevation of labial ridges of this species refers it to *Ptychophylloceras* but detail identification can not be made because of the bad preservation.

Occurrence: – Horizon of *Protacanthodiscus akiyamai* at Isokusa, Isokusa Formation, Berriasian.

Order Ammonitida Zittel, 1884
Superfamily Perisphinctaceae Steinmann, 1890
Family Olcostephanidae Haug, 1910
Subfamily Spiticeratinae Spath, 1924
Genus *Spiticeras* Uhlig, 1903

Type-species: – *Ammonites spitiensis* Blanford, 1863

Spiticeras (*Spiticeras*) cf. *binodiger* Uhlig, 1903

Spiticeras (*Spiticeras*) cf. *binodiger* Uhlig, Sato, 1961, p. 548, pl. 12, fig. 2, pl. 13, fig. 1.

Remarks: – One spinose ammonite of moderate size from Nagasaki was recorded by Sato (*loc. cit.*). There is no additional information about it.

Occurrence: – Uncertain, probably lower part of sequence at Nagasaki, Berriasian.

Genus *Olcostephanus* Neumayr, 1875

Type-species: – *Ammonites astierianus* D'Orbigny, 1840.

Synonyms: – *Holcostephanus* Sayn, 1889; *Astieria* Pavlow, 1892; *Rogersites* Spath, 1924; *Taraisites* Cantu Chapa, 1966.

Olcostephanus sp.
Pl. 37, fig. 10

Olcostephanus nov. sp., Sato, 1958, p. 590, pl. 28, figs. 1–3, text-fig. 2.
Olcostephanus sp., Takahashi, 1969, p. 27.

Material: – Three specimens. IGPS coll. cat. no. 87140-b; GIUM 40771, 40772.

Remarks: – The species which is abundant in the upper part of the Isokusa Formation (middle part of Nagasaki sequence) at Nagasaki, Oshima Island, was described and discussed by Sato (*loc. cit.*) and there is nothing to be added at present.

From the discussion by Riccardi *et al.* (1971) about the age and distribution of the genus *Olcostephanus*, the age of this species may be better raised to Valanginian. The Berriasian age was assigned by Sato who correlated his species to the undescribed (presumedly) *Rogersites* from the Berriasian of the Alps.

The isolated occurrence of this species makes it difficult to determine its age but from the range of the genus and the stratigraphic position of the locality it is considered to be middle and/or upper Valanginian.

Occurrence: – Cited above.

Family Berriasellidae Spath, 1922
Subfamily Berriasellinae Spath, 1922
Genus *Berriasella* Uhlig, 1905

Type-species: – *Ammonites privasensis* Pictet, 1867
Synonym: – *Stenoceras* Uhlig, 1910

Berriasella sp. A
Pl. 36, figs. 4–6

? *Berriasella* sp. nov. *ex gr. B. berthei* Toucas- *oppeli* Kilian, Sato, 1958, p. 595, pl. 28, figs. 4–7.
Berriasella sp. Takahashi, 1969, p. 72.

Material: – Three fragmental specimens. IGPS coll. cat. no. 87139-a, an internal mold partly with last and penultimate whorls; GIUM 40751, partly preserved internal mold of last (presumed) whorl; GIUM 40752, fragmental internal and external molds of immature individual.

Remarks: – Evolute, compressed whorls with sharp, bifurcate, slightly flexuous ribbing characters (no. 87139-a) resemble *Berriasella* sp. ex gr. *B. berthei* from Nagasaki described by Sato (loc. cit.). Many simple ribs, smooth, furcating without tubercles, and deep parabolic constrictions of the specimen are due to its more matured stage. The second specimen (GIUM 40751) though fragmental has the same ribbing as the preceding one. The third specimen is an immature individual (diameter of about 48 mm) from the pelecypod bank of the lowermost part (Ik-1) of the Isokusa Formation at Niranowaki. The specimen has less frequent unbranched ribs compared with the other two and has minute tubercles at the points of furcation at about 15 to 25 mm in diameter. Such minute tubercles are seen in some of Sato's specimens. This specimen though it shows different growth stage and is not directly comparable with the other two is tentatively assigned to the same species as the preceding ones and to the species recorded by Sato.

Occurrence: – IGPS coll. cat. no. 87193-a is without its precise locality. It is presumably from Isokusa judged from its preservation and lithology of the matrix. Presumably Berriasian. GIUM 41751 is from lower part of Ik-3 (Isokusa Formation) at Niranowaki. Berriasian. GIUM 40752 is from the pelecypod bank of the lowermost part of Isokusa Formation (Ik-1) at Niranowaki. Latest Tithonian.

Berriasella sp. B
Pl. 36, fig. 3

Material: – One specimen. GIUM 40753.

Description: – Form small [D, 74; U, 25 (0.34); H, 30 (0.43)], planulate, ribs dense, flexuous, furcation rather irregular, most ribs furcate into two secondaries at about two thirds of flank from umbilical margin. Some ribs simple, thirty-one primaries on half of outer whorl. Doubtful narrow constrictions represented by conjugation of adapical ribs present.

Remarks: – This specimen probably belongs to the group of *Berriasella privasensis* (Pictet) of Mazenot's (1939) classification by its non tuberculate, flexuous and bifurcate ribbing, but differs from the preceding species by having more flexuous and denser ribbing.

Occurrence: – Lower part of Isokusa sequence (horizon of *Protacanthodiscus akiyamai*). Isokusa Formation, Berriasian.

Genus *Protacanthodiscus* Spath, 1923

Type-species: – *Hoplites andreaei* Kilian, 1889.

Synonyms: – *Malbosiceras* Grigorieva, 1938: ? *Pomeliceras* Grigorieva, 1938.

Protacanthodiscus akiyamai (Sato), 1961
Pl. 36, figs. 1, 2

Berriasella akiyamae Sato, 1961, p. 544, pl. 13, figs. 4–6.
Berriasella akiyamai Sato, Takahashi, 1969, p. 27.

Material: – Three specimens. IGPS coll. cat. no. 87138-a, GIUM 40766, 40767.

Remarks: – The holotype from Isokusa described by Sato (*loc. cit.*) shows the peculiar costation of *Berriasella*, and was regarded as a form transitional from *Berriasella* to *Neocosmoceras*.

The three specimens, which though lack the gerontic whorls seen in Sato's specimen (1961, pl. 13, fig. 5) and attain 210 mm in diameter according to Sato, show the same peculiarity and agree with the holotype in form and costation.

The ribs are generally prominent, straight and slightly prorsiradiate on flank side. Every two or more ribs is stronger, more elevated, tuberculate; and bear tabulate bullae at umbilical margin and prominent tubercles or in some cases spines at about two thirds of flanks from umbilical margin. Ribs somewhat swell from tubercles and bend forward slightly, in a few cases they do not furcate. Beside tuberculate ribs, sets of elevated ribs forming shallow constrictions are sporadically present. They are not tuberculate except at umbilical edge where tabulate terminal of ribs point to umbilicus (or center of volution). These ribs and constrictions correspond with flared ribs and transverse grooves on gerontic whorl (Sato, 1961, pl. 13, fig. 5).

Scarcity of furcation causes widening of interspaces at circumferential area with increasing radius though it is relieved partially by thickening of ribs toward periphery. This with rigidity and differential strength of ribbing makes this species rude and stiff in appearence.

This species appears distinct from the typical *Berriasella* that has generally regular and graceful costation. The characters of this species resemble those of *"Berriasella" andreaei* (Kilian, 1889) that was chosen as the type-species of *Protacanthodiscus* by Spath, though some characters such as much furcated ribbing and polygonal whorl sections at least of the outer whorl seem to have little congruence with the present species.

The rude form of this species is somewhat analogous with some neocomitinid ones as *Neocosmoceras* and *Neohaploceras*. They may have relation with this species as discussed by Sato.

In spite of a little discongruency between this species and "*B.*" *andreaei* the present one is allied with "*B.*" *andreaei* and its group, namely, "*B.*" *malbosi* (Pictet, 1867), "*B.*" *tarini* (Kilian, 1889), "*B.*" *broussei* Mazenot, 1939, "*B.*" *paramimouna* Mazenot, 1939, *etc.* These are now considered to belong to *Protacanthodiscus* Spath, 1923.

The terminal group of perisphinctaceans including berriasellinids, neocomitinids and himalayaitinids seems to be disordered in classification. To avoid confusion lumping up of many species having more or less successive characters is one of the acceptable treatments at present as pointed out by Mazenot (1939) in his monograph of "Palaeohoplitidae" (he lumped about 80 species including unidentified ones into the single genus *Berriasella.*).

In this paper, however, *Protacanthodiscus* is adopted though some disputation may remain in the limits of generic application.

Occurrence: – Black sandy mudstone of west coast of Isokusa. Horizon lower than that of *Thurmanniceras isokusense*. Holotype recorded only as from the Isokusa Formation at Isokusa but was probably from the same horizon as the present specimens. Isokusa Formation. Age is Berriasian (supposedly early to middle).

Protacanthodiscus aff. *malbosi* (Pictet), 1889
Pl. 37, fig. 9

Affinis.

Ammonites malbosi Pictet, 1867, p. 77, pl. 14, figs. 1–2. (*fide* Mazenot).
Berriasella malbosi (Pictet), Mazenot, 1939, p. 98, pl. 13, figs. 8a-c (lectotype=Pictet, 1867, pl. 14, fig. 1), pl. 14, fig. 1.
Berriasella malbosi (Pictet), Arnould-Saget, 1951, p. 52, pl. 5, fig. 7.
Protacanthodiscus malbosi (Pictet), Nikolov, 1960, p. 174, p. 14, fig. 4; pl. 15, fig. 1.

Material: – One fragmental specimen. IGPS coll. cat. no. 87140-a.

Fig. 4. Terminal suture line of *Protacanthodiscus* aff. *malbosi*. Dotted line of center of lateral lobe shows bulged band on internal mold.

Remarks: – The specimen consists of nearly one third of the last whorl of a fairly large (exceeding 150 mm in diameter) ammonite, represented by body chamber and the last part of the phragmocone.

Form moderately evolute, compressed with nearly perpendicular umbilical wall: flank side rather flat, slightly convergent in peripheral half of flank: ventral area crushed but seems to be more or less shouldered by bullate ribs and blunt venter.

Primaries distant, strong, rounded at ridge, originate from umbilical edge where they form bullae, then bear prominent tubercles near middle of flank. From tubercles primaries branch into two or three secondaries; two or three free secondaries or intercalatories present between tuberculate primaries. Secondaries low, obtuse, wider than interspaces. Some secondaries swell at shoulder, very blunt at venter, cross it without interruption.

Remarks: – The species is a new form in Japan, and resembles *Protacanthodiscus malbosi* (Pictet) from the Berriasian (=Infra Valanginian) of central Europe and western Tethys region. The much compressed whorl section and lower position of furcation of this specimen compared with the lectotype (Mazenot, 1939, pl. 13, figs. 8a-c) from southeast France are mainly due to post-depositional deformation but the original character is well recognized. A specimen from Jebel Nara (central Tunisia) described by Arnould-Saget (1951, pl. 5, fig. 7) seems to have rather compressed whorl section and flat flank side.

The present species may be close to the mentioned ones, but at present it seems best to refrain from naming until better material is found.

Protacanthodiscus is known from the Berriasian, especially the middle part (lower part of "*Subthurmannia*" *boissieri* zone of southeast France), of southeast France (Berrias, La Faurie, *et albi*), Barealic Island (North Range of Majorca), Algeria (Lamoricière), Tunisia (Jebel Nara), eastern Pre-Balkan Mountains (Elena and Turgovishte districts), and Caucasus.

The genus *Malbosiceras* was proposed by Grigorieva (1938) based on *Ammonites malbosi* Pictet, but it does not seem to have been adopted in general. This genus is ignored by Arkell *et al.* (*in* Moore ed., 1957), is regarded as a synonym of *Protacanthodiscus* Spath by Luppov *et al.* (*in* Orlov ed., 1958), though it is introduced and its validity recognized by Howarth (1960). In the present paper the writer provisionally follows Luppov *et al.*

Horizon: – Isokusa Formation at Nagasaki. The detailed record of occurrence of this specimen is missing, but probably it came from the lower part of the Nagasaki "block". Age is supposedly Early or Middle Berriasian.

Genus *Substeueroceras* Spath, 1923

Type-species: – *Odontoceras koeneni* Steuer, 1897.

Substeueroceras sp.
Pl. 36, figs. 9–12

Substeueroceras sp., Sato, 1962, p. 96, pl. 4, figs. 8–10.
Substeueroceras sp., Takahashi, 1969, p. 27.

Material: – Seven specimens. GIUM 40776-40782.

Remarks: – This species, first recorded by Sato (*loc. cit.*), is abundant in the black shale (Ik-2) of the Isokusa Formation at Niranowaki, but scarce in the subjacent pelecypod bank (Ik-1) of the same formation.

The slightly sigmoidal, irregular ribbing of this species shows that it may belong to the named genus, but the fine costation and rather high furcation points resemble *Kossmatia*.

The Upper Tithonian age determined by Sato for this species correlating it with the *Substeueroceras koeneni* zone of the Andean Jurassic may be correct though its specific position needs further investigation.

Occurrence: – Abundant in the black shale (Ik-2) of the lower part of the Isokusa Formation and rare in the pelecypod bank (Ik-1) of the same formation both at Niranowaki. Age, presumably uppermost Tithonian.

Substeueroceras ? sp.
Pl. 36, figs. 7, 8

Substeueroceras ? sp., Takahashi, 1969, p. 27.

Material: – One specimen. IGPS coll. cat. no. 87141.

Remarks: – A fragment of a small (about 65 mm in diameter), involute and compressed ammonite with dense and fine ribbing is in the collection. The precise record of occurrence is unknown but it probably is from the black sandy mudstone of the Isokusa Formation at Isokusa.

Ribs inclined forwardly and furcate at the middle of flanks into two, three or more secondaries; some ribs take virgatotome furcation; simple ribs and intercalatories present. Ribs become gradually fasciculate at apertural area. Venter not sulcate. Constrictions not present on observable outer whorl. Aperture and suture lines not preserved.

The projected, less flexuous ribs and rather high position of furcation are suggestive of the costation of *Kossmatia* but the not interrupted venter is hardly referable to that genus. Relatively regular ribbing and some virgatotome furcation may refer this specimen to some virgatosphinctinid genera, but at present the specimen is placed tentatively in *Substeueroceras*.

Occurrence: – Probably from the *Protacanthodiscus akiyamai* bed of Isokusa, middle part of the Isokusa Formation. Age, Berriasian.

Subfamily Neocomitinae Spath, 1924
Genus *Thurmanniceras* Cossmann, 1901

Type-species: – *Ammonites thurmanni* Pictet and Campiche, 1858–60.

Synonyms: – *Thurmannia* Hyatt, 1900 (non Heer, 1852); *Thurmannites* Kilian and Reboul, 1914.

Thurmanniceras isokusense (Kobayashi and Fukada, 1947)
Pl. 37, figs. 1–8

Perisphinctes (*Parabolicaras*) sp. nov., Shiida, 1940, p. 45.
Perisphinctes (*Discosphinctes*) *isokusense* Kobayashi and Fukada, 1947, p. 55, pl. 13, figs. 2–4.
Thurmanniceras isokusensis (Kobayashi and Fukada), Sato, 1958, p. 592, pl. 28, figs. 9–12.
Thurmanniceras isokusense (Kobayashi and Fukada), Takahashi, 1969, p. 27.

Material: – 13 specimens. IGPS coll. cat. nos. 87138–b, 87139–b, GIUM 40754 –40764 (11 specimens).

Remarks: – This species is abundant in the Isokusa Formation at the west coast of Isokusa (upper part of sequence). The specimen assigned to this species from the east coast of Niranowaki is from beach gravel, but it probably is from the cliff just behind the beach. The black sandy mudstone of the locality is more or less equivalent in age with the Isokusa Formation at Isokusa.

The specimens have in general blunt ribs but some small specimens have rather distinct ribs. Manner of furcation such as position of and numbers of furcation is also variable among individuals. Costation changes ontogenetically from less flexuous and less furcated ribbings in younger whorls (less than about 20 mm in diameter) to more flexuous and much furcated ribbing in more aged whorls. In larger whorls (more than 50 mm in diameter, presumedly last whorl of macroconch individual) ribs are degenerated, at any rate, at flank side, and in some specimens the ribs become very faint except at umbilical and ventral margins where they are more or less tuberculate and bullate. Such degenerated costation is seen in *Thurmanniceras pertransiens* Sayn from the Lower Valanginian of southeast France (Sayn, 1907, p. 43, pl. 4, fig. 14, pl. 5, figs. 10–11, 15–17; Mazenot, 1939, p. 205, pl. 32, fig. 16 as *affinis*) and from the eastern Pre-Balkan range (Nikolov, 1960, p. 176, pl. 18, fig. 2).

The ribs disappearing on the outer whorl with persistent umbilical tubercles and ventral bullae are analogous to the ribbing of *Dalmasiceras*, but this species has more involute (narrow umbilicus) form in larger stage, and rather blunt, irregular and flexuous ribbing through the stages compared with those of *Dalmasiceras*, though difficulty arises in discrimination of this species from some forms of *Dalmasiceras* when only crushed degenerated outer whorls occur.

Haas (1960, p. 60) pointed out the similarity of costation between this species (figured by Sato, *loc. cit.*) and his *Substeueroceras mutabile* from the Lower Berriasian of Colombia, South America. *Thurmanniceras isokusense* has, as he acknowledged, ventral groove at least in younger whorls though in older whorl the sulcation becomes blunt, and such a character is never attributable to *Substeueroceras*. The shape of the lappets in one small specimen (GIUM 40756) of *T. isokusense* is quite different from that of *S. mutabile* (his p. 23, fig. 48). The former have simple rod-like lappets with smooth apertural area in contrast to spatulate lappets with no degenerated sharp ribs at the aperture. Some resemblance between this and the Colombian species is, therefore, superficial.

Another problem is that the specimens seems to represent dimorphism. One group of specimens is larger in size (about 6–8 cm in diameter) with compressed whorl section and narrow umbilicus due to rapid growth of whorl height in the adult and/or gerontic stages. Ribbing of those larger specimens are less flexuous and much furcated or fasciculate at least on the mature whorls, and on gerontic whorls ribs are more or less degenerated as mentioned above. Another group is smaller in size (about 4–5 cm in diameter) with more depressed whorl section and relatively wide umbilicus. Ribbing of the smaller specimens is rather conspicuous and more flexuous than those of the larger ones, showing irregularity and a few branching.

Such phenomena might be explained by ontogenetical mutation, but one specimen (GIUM 40756) represents attach lappets and degenerated costation near the aperture. The degeneration of costation conforming to the shape of the lappets are observable in the other small specimens (GIUM 40757, 40758) though the lappets are not preserved in these specimens. The presence of lappets and degeneration and modification of costation near the aperture are generally accepted as characteristic of maturity, and such form as smaller with lappets is regarded as a male and the larger form without lappets is regarded as the female by most recent authors. The smaller forms of *T. isokusense* are, therefore, adult and presumably male individuals and the larger forms are female individuals. Those two forms appearing from the same horizon of the same locality and having similarity in their characters except ones mentioned above may be conspecific, though the presence or absence of lappets is sometimes regarded as a supra-specific character in customary classification of ammonites.

Mutability and indistinctness of costation make it difficult to identify the specific position of each specimen. Flexuous fasciculate ribbing with lower position of branching, and narrow umbilicus and sulcate venter of this species are, however, apparently distinguishable from those of other berriasellinids of this area, and are most referable to the characters of *Thurmanniceras* as stated by Sato (*loc. cit.*).

Occurrence: – Abundant in the upper part of the black sandy mudstone at the west coast of Isokusa, Oshima Island. Rare (one specimen) in the black sandy mudstone at the east coast of Niranowaki, Oshima Island. Horizon, middle part of the Isokusa Formation (Ik-3 of Niranowaki sequence). Age, Berriasian according to Sato (1958, 1961). It is, however, considered to be Early Valanginian in age in general accordance with the range of this genus in Tethyan and Central European regions.

Genus *Kilianella* Uhlig, 1905

Type-species: – *Hoplites pexiptychus* Uhlig, 1881.

Kilianella sp.
Pl. 36, fig. 13

Material: – Two specimens. IGPS coll. cat. no. 87974; GIUM 40765.

Remarks: – One figured specimen (IGPS coll. cat. no. 87974) found in the unregistered collections (register number alloted herein) housed in the Institute of Geology and Paleontology, Tohoku University seems to be a counter part of Sato's figured specimen (1958, pl. 28, fig. 8).

The small form of the specimen is presumed by Sato as a juvenile, but the present specimen possesses elongate lappets and modified apertural ribs with apertural constriction, which are not preserved in Sato's specimen. This suggests the specimen to be an adult.

Another specimen (GIUM 40765) obtained from the same bed as *Thurmanniceras isokusense* at Isokusa is represented by a small part of the peripheral area of a small ammonite. Such characters as prominent but no sharp ribs projected and bullate at ventral shoulder and then interrupted by ventral groove resemble the Nagasaki specimen with which it may be conspecific.

Kilianella sp. recorded by Sato and Takizawa (*in* Takizawa, 1970, p. 570, pl. 44, fig. 3) from the Ayukawa Formation of Aji-shima Island, Ojika area, and compared with this specimen by them will not be discussed owing to the bad preservation of both the present and Ayukawa specimens.

Occurrence: – Rare in the black mudstone of Nagasaki (precise locality and horizon is not known) and *Thurmanniceras* bed of Isokusa Formation at Isokusa. Supposedly Early Valanginian in age.

Incertae Sedis

Remarks: – One gigantic ammonite attaining more than 120 cm in diameter, found from the pelecypod bank of Ik-1 of Niranowaki is now stored in the National Science Museum, Tokyo. From the photographs kindly sent to the writer by Mr. Shimoyama, the finder, the peripheral areas of the last and penultimate (and ? antepenultimate) whorls are not be observable, but the specimen appears to be a gigantic member of perisphinctacians. From the rather dense ribbing of the inner whorls and distant, somewhat bullate (on dorsolateral area) ribbing at the outer whorl it may be a compressed member of dorsoplanitinids, or from its compressed form, a ribbed member of tollinids (*sensu* Donovan, 1964), both are giant members of the Latest Jurassic and Early Cretaceous ammonoids of boreal and northwestern Europe. Further discussion is reserved until the specimen is studied.

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Plate 36

(All figures in natural size unless stated otherwise)

Figs. 1, 2. *Protacanthodiscus akiyamai* (Sato).
1-IGPS coll. cat. no. 87138-a. Gypsum cast taken from external mold. Loc. Isokusa. 2-GIUM 40766. Gypsum replica of internal mold. Loc. Isokusa.

Fig. 3. *Berriasella* sp. B.
GIUM 40753. Gypsum cast taken from external mold. Loc. Isokusa.

Figs. 4–6. *Berriasella* sp. A.
4-IGPS coll. cat. no. 87139-a. Internal mold. Loc. presumedly Isokusa. 5-GIUM 40752. Internal mold. Loc. Niranowaki (Ik-1). 6-Kesennuma High School Collection. External mold. × 3/5. This is a counter part of Sato's specimen (1958, pl. 28, fig. 8. Fragmental internal mold). According to the label, the locality of the specimen is Onozaki of Isokusa, but the locality is mentioned as Nagasaki, by Sato.

Figs. 7, 8. *Substeueroceras* ? sp.
7-IGPS coll. cat. no. 81141. Silicone rubber cast taken from external mold. Loc. Presumedly Isokusa. 8-Same specimen as fig. 7. Ventral view of internal mold.

Figs. 9–12. *Substeueroceras* sp.
9-GIUM 40778. Gypsum replica of internal mold. Loc. Niranowaki (Ik-2). 10-GIUM 40781. Internal mold. Loc. Same as above. 11-GIUM 40777. Internal mold of juvenile specimen. Loc. Same as above. 12-GIUM 40776. Internal mold. Loc. Same as above.

Fig. 13. *Kilianella* sp.
IGPS coll. cat. no. 87974. External mold and partly internal mold of other (left) side at apertural area. Note lappets. Loc. Nagasaki.

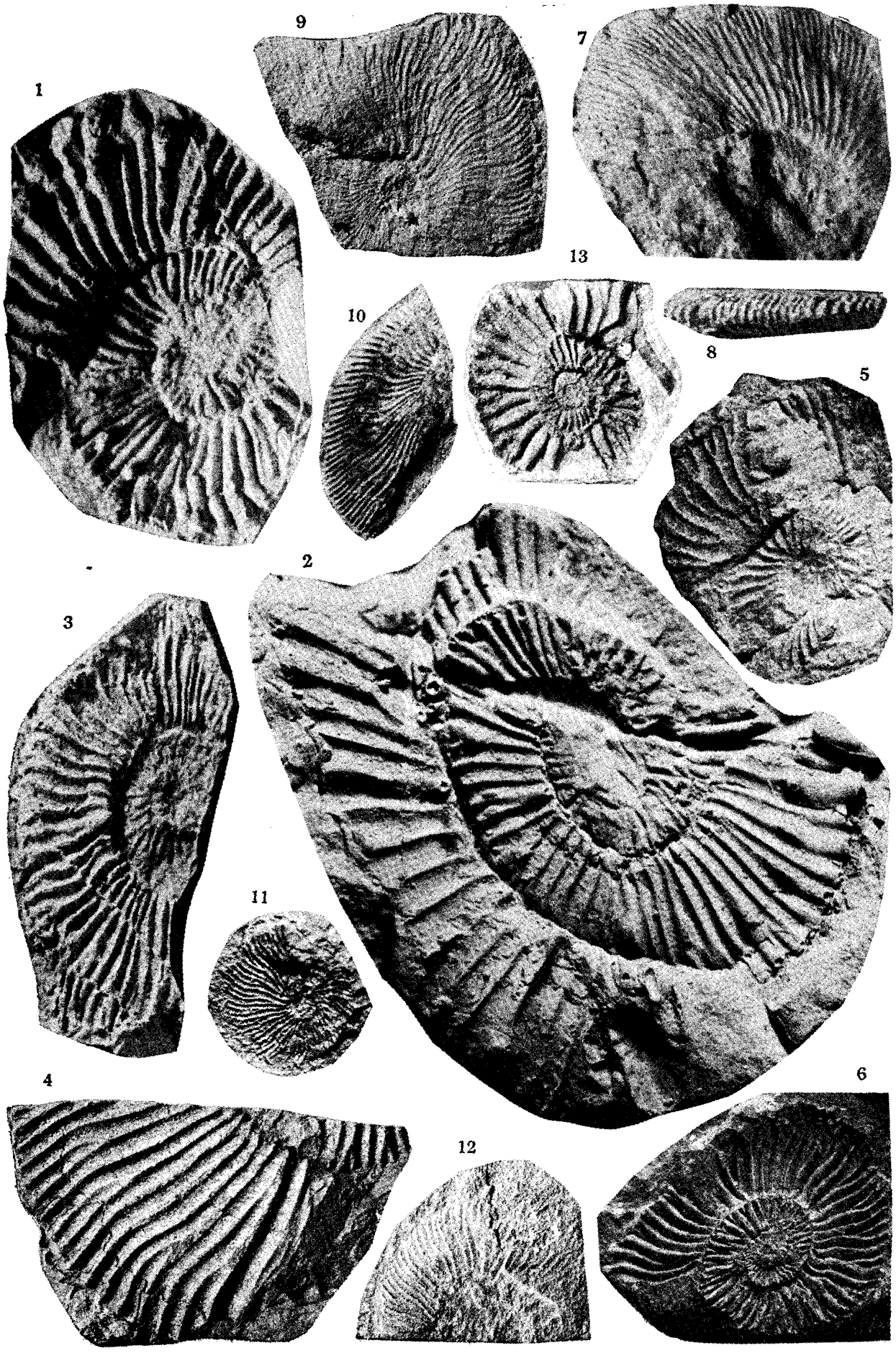
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Plate 37

(All figures in natural size)

Figs. 1–8. *Thurmanniceras isokusense* (Kobayashi and Fukada).
1-GIUM 40755. Silicone rubber cast taken from external mold. Loc. Isokusa. 2-GIUM 40758. External mold and internal mold of another (left) side at apertural area. Loc. Same as above. 3-IGPS coll. cat. no. 87138-b. Internal mold. Loc. Same as above. 4-GIUM 40764. Gypsum replica of internal mold. Loc. Niranowaki (Ik-3). 5-GIUM 40757. Gypsum cast taken from external mold. Loc. Isokusa. 6-GIUM 40754. Gypsum cast taken from external mold. Note dorsal tuberculation and degenerated costation. Loc. Same as above. 7-IGPS coll. cat. no. 87139-b. Gypsum cast taken from external mold. Note dorsal tuberculation and lower position of branching. Loc. Same as above. 8-GIUM 40756. Internal mold with lappets. Loc. Same as above.

Fig. 9. *Protacanthodiscus* aff. *malbosi* (Pictet).
IGPS coll. cat. no. 87140-a. Body chamber with the last part of phragmocone; last suture line is partly preserved. Shell material is partly preserved, which is a rare case in specimens of this area. Loc. Nagasaki.

Fig. 10. *Olcostephanus* sp.
IGPS coll. cat. no. 87140-b. Internal mold. Loc. Nagasaki.